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Description

Carding Machine for Bundled Fibers

Technical Field

This invention relates to a machine that cards bundled fibers, wherein the bundled fibers composed of many fiber filaments travel through a carding unit, into which fluid flows orthogonal to the moving direction of the bundled fibers applying moving force to the bundled fibers so as to extend its widthwise direction to card into a sheet.

Background Art

In recent years, many fiber-reinforced composite materials, in which carbon fibers, glass fibers, or aromatic polyamide fibers as reinforcing material are impregnated in the form of a filament or fabric into a matrix like a synthetic resin, have been developed and are available on the market.

By correctly selecting both the matrix and reinforcing material, these fiber-reinforced materials have a wide-range of excellent properties that can be matched to the desired objective with respect to mechanical strength, heat resistance, corrosion resistance, electric properties, and weight reduction and are widely used in the field of aerospace, land transportation, shipping, building, construction, industrial parts, and sporting goods.

There are two types of usage of the reinforcing fibers. One is where the structure is impregnated with the reinforcing filaments into a matrix; the other is by parallel alignment of many filaments wide enough to cover the width of the matrix. In the latter type, it is desirable to make the contact area between the matrix and reinforcing filaments as large as possible. Therefore, many reinforcing filaments treated with an adhesive (sizing agent) are bundled in a form of a flat or ellipsoidal cross-section to form the bundled fibers, in which each reinforcing filament is aligned as to minimize the space between them, yielding a thin but wide carded sheet. Impregnation of this sheet in the matrix promotes the matrix to impregnate into the minimum space, maximizing the contact area between the matrix and the reinforcing filament and showing the maximum fiber reinforcing effects by the reinforcing filaments.

For this purpose, an airflow carding machine for the bundled fibers is proposed, wherein a so called suction wind tunnel pipe with a required traverse width is placed facing a moving path from a supply unit (feed roll) of bundled fibers to a take-up section (rewind roll), and the bundled fibers (for example, multifilament) in a certain overfed condition are continuously suctioned to bend the bundled fibers into a crescent shape and to card in the widthwise direction (Japanese Patent Publication No. 3,064,019).

The airflow carding machine for the bundled fibers disclosed in this Japanese Patent Publication No. 3,064,019 can effectively card in parallel, the bundled fibers of very long multifilaments without causing damage.

As shown in Figure 17, the bundled fibers 1 are drawn out from a feed roll A that then travels through front feeder 2, which is composed of a drive roll 2a and a free revolving roll 2b, into which an airflow carding unit 3 cards to yield a carded sheet 1a. This carded sheet 1a is fed through a back feeder 4 to rewind around a rewind roll B, and the degree of bending of bundled fiber 1 traveling through suction wind tunnel 3a in the airflow carding unit 3 is detected by the fiber height detection unit 5 in the airflow carding machine for the bundled fibers 1.

As shown in this figure, the fiber height detection unit 5 tries to use a method of controlling the level of bending of the bundled fibers 1, by pressing down the whole bundled fibers 1 with a wire-like fiber height sensor unit 5a, detecting the location of a retaining unit 5b that is tied with this fiber height sensor unit 5a by a sensor 5c, which feeds back the detected signal to a driver motor of the driving roll 2a in the front feeder 2. It adjusts the number of revolutions and controls the amount of the bundled fibers 1 drawn out by the drive roll 2a and free revolving roll 2b, adjusting for amount of overfeeding and controlling the amount of bending.

Disclosure of Invention

Problems to be solved by the invention

As shown in Figure 18, more than one airflow carding unit 3_1, 3_2, and 3_3 is aligned to form a multistage in the moving direction of the bundled fibers since a single airflow carding unit 3 alone cannot sufficiently card the bundled fibers collected with many filaments. In this case, as shown in Figure 18, feed roll units 2_1, 2_2, 2_3, and 4 are installed before and after each airflow carding unit 3_1, 3_2, and 3_3 together with the aforementioned fiber height detection units 5_1, 5_2, and 5_3 at each airflow carding unit 3_1, 3_2, and 3_3, respectively, in order to make the carding process proceed smoothly at each airflow carding unit 3_1, 3_2, and 3_3.

The main objective of the present invention is to provide a carding machine capable of continuously carding the bundled fibers without detecting the level of bending of the bundled fibers in the carding unit by the fiber height detection unit that feedbacks its detected signal to the driver motor for the drive roll of the front feeder to control the depth of bending as in a conventional machine.

Another purpose of the present invention is to provide a compact, lightweight, and economical carding machine for the bundled fibers, wherein more uniform and highly carded filaments can be constantly produced by use of one or more supportive parts with a small diameter in the carding unit.

An additional objective of the present invention is to simplify the support structure of the feed roll such that the required space for installation is reduced and obtain a carding machine with multiple spindle or multiple spindle multistage bundled fibers.

Means for solving problem

In order to achieve the aforementioned objective, the carding machine for bundled fibers in the present invention is first characterized by having the carding unit to card the bundled fibers that are fed from a feed roll wound with the bundled fibers; by flowing fluid in a direction orthogonal to the direction of the moving bundled fibers; by having a rewind roll rewinding the carded sheet in the carding unit; and by having one or more supportive parts placed in a certain interval along the moving direction in the aforementioned carding unit.

In this setup, the direction that the fluid flows in the carding unit can either suction the fluid flowing downward, from above to below, or flowing upward, from below to above, so long as the fluid flows in the direction orthogonal to the moving direction of the bundled fibers. Similarly, this relationship holds in the case where the flow direction is from right to left or from left to right.

Increasing the number of supportive parts in the said carding unit reduces the interval distance as well as the

bending of the bundled fibers between the supportive parts, whereas increasing their diameter increases the modulus of supportive parts to prevent bending and reducing their interval distance, leading to a decrease of bending of the bundled fibers between the supportive parts. However, increasing the number of supportive parts or the diameter tends to excessively reduce the flow area of the fluid, along with reducing the interval distance, resulting in a decrease in the carding efficiency of the fluid. Therefore, the number, diameter, and interval distance of said supportive parts need to be properly set according to the kind of bundled fibers, the diameter and number of the filaments, and the kind of a sizing agent.

The aforementioned one or more supportive parts that are installed at a particular interval are properly placed linearly and horizontally, tilted, or in a crescent shape, according to the type of bundled fibers, the diameter and number of the reinforcing filament, and the kind of sizing agent. (Refer to Figure 4 (A), Figure 6 (B), and Figure 8.)

In the carding machine for the bundled fibers in the present invention, the said carding unit is secondly characterized by having a frame forming a flow path for the fluid internally and possessing both a large diameter guiding part placed at the front and back ends of the guiding part in the moving direction of the bundled fibers and one or more small diameter supportive parts placed between these guiding parts.

The carding machine for the bundled fibers in the present invention is thirdly characterized by a guiding and/or supportive part in the aforementioned carding unit having a roughly cylindrical form and a fixed or revolvable form around a shaft.

The carding machine for the bundled fibers in the present invention is fourthly characterized by placing the aforementioned multiple supportive parts in a plane or roughly, in a crescent, against the moving direction of the bundled fibers.

The carding machine for the bundled fibers in the present invention is fifthly characterized by placing the aforementioned carding unit in multistage along the moving direction of the bundled fibers.

The carding machine for the bundled fibers in the present invention is sixthly characterized by increasing stepwise or continuously the width of the moving path of the bundled fibers in the aforementioned multistage carding unit with the direction going from upstream to downstream.

The carding machine for the bundled fibers in the present invention is seventhly characterized by placing the shaft of the aforementioned feed roll in a vertical direction. Here, "vertical direction" includes not only a geometrically perpendicular arrangement, but also a tilted arrangement at a certain angle relative to the perpendicular.

The carding machine for the bundled fibers in the present invention is eighthly characterized by placing more than one aforementioned feed rolls.

The carding machine for the bundled fibers in the present invention is ninthly characterized by placing more than one carding unit in parallel and orthogonal to the moving direction of the bundled fibers.

The carding machine for the bundled fibers in the present invention is tenthly characterized by consolidating the carding unit into a single carding form that shares a part of the component part, wherein the carding unit is placed in multistage along the moving direction of the aforementioned bundled fibers, and/or more than one carding unit is placed in parallel and orthogonal to the moving direction of the bundled fibers.

An eleventh characterization of the carding machine for the bundled fibers in the present invention is a fluid path filled with a heated fluid.

A twelfth characterization of the carding machine for the bundled fibers in the present invention is heating of the guiding and/or supportive parts in the aforementioned carding unit.

A thirteenth characterization of the carding machine for the bundled fibers in the present invention is having the aforementioned guiding and/or supportive parts with a built-in heater.

A fourteenth characterization of the carding machine for the bundled fibers in the present invention is having the aforementioned guiding and/or supportive parts in a pipe shape, in which heated fluid is circulated.

A fifteenth characterization of the carding machine for the bundled fibers in the present invention is having a slit in the aforementioned pipe shaped guiding and/or supportive parts that crosses in the moving direction of the bundled fibers, wherein the heated fluid is ejected from this slit.

Advantageous Effect of the invention

According to the first characteristic of the structure of the carding machine for the bundled fibers in the present invention, the carding unit possesses one or more supportive parts orthogonal to the moving direction of the bundled fibers and the carding action in the conventional wind tunnel pipe performed by passing the bundled fibers and the carded sheet over one or more supportive parts aligned at small intervals is done before and after on both sides of the single supportive part, or continuously done before and after in small stepwise intervals for each of the more than one supportive parts, leading to more reliable carding action and better quality in carding.

Furthermore, the bundled fibers moving in the carding unit is constantly carded, responding to the alignment

condition of one or more supportive parts. Therefore, it is not required to use the conventional method, in which the height of the moving bundled fibers is balanced by an airflow suction force with the tension of the bundled fibers to bend into a crescent form that is constantly detected by the fiber height detection unit and fed back to the driver motor of the drive roll of the front feeder to control for the amount of overfeeding of the bundled fibers fed from the front feeder. Omitting the fiber height detection unit between carding units in each step, as well as the front feeder, particularly in a multistage carding machine, leads to a smaller, lightweight, cheaper carding machine.

As it relates to the setup of the second characteristic of the carding machine for the bundled fibers in the present invention, a large diameter guiding part is placed at the front and at the end of the frame in the moving direction of the bundled fibers, and the bundled fibers are stably fed into the carding unit that stably comes out from the carding unit. Furthermore, one or more small diameter supportive parts are installed between these guiding parts, and the bundled fibers moving in the carding unit can be kept at constant configuration that responds to the placement of the single or multiple supportive parts, leading to uniform carding and then an elimination of the requirement of detecting the fiber height in the carding unit. Using smaller diameter supportive part makes the fluid

flow path area larger to improve carding action in the carding unit.

In regards to the structure of the third characteristic of the carding machine for the bundled fibers in the present invention, the guiding and/or supporting parts are roughly cylindrical and are either fixed or revolvable around the shaft, where the friction force generated by the flow force of the fluid from the guiding and/or supporting parts apply smooth carding action to the moving bundled fibers over the guiding and/or supportive parts. When the guiding and/or supportive parts are fixed, their structure becomes simple and the machine can be manufactured at low cost. When the guiding and/or supportive parts are able to revolve around the shaft, they revolve around the shaft by moving bundled fibers as to make its movement smooth and reduce the friction between the bundled fibers and the guiding and/or supportive parts. Furthermore, the area of friction can be diffused in a circumferential direction to prolong the life of the guiding and/or supportive parts.

According to the setup of the fourth characteristic of the carding machine for the bundled fibers in the present invention, more than one supportive part is placed in a plane or approximately in a crescent shape against the moving direction of the bundled fibers, and the bundled fibers moving on the supportive parts can move and be carded constantly, keeping a planar or crescent configuration against the moving

direction according to the setup of the supportive parts, making efficient carding possible. In the case that the bundled fibers are carded in the crescent configuration, excess mass of the overfed bundled fibers can be absorbed by sinking of the fibers so that the contact area between the bundled fibers and fluid is increased, improving the carding efficiency especially when compared to the case where multiple supportive parts are set flat.

According to the setup of fifth characteristic of the carding machine for the bundled fibers in the present invention, the carding unit is aligned in multiple stages along the moving direction of the bundled fibers, and carding of the bundled fibers is processed step by step and smoothly moving along the bundled fibers over the multistage carding unit from upstream to downstream. In this case, not only the fiber height detection unit at each carding unit, but also the front feeder upstream of each carding unit is not required, so as to simplify, miniaturize, lighten, and minimize cost and shorten the total length of the carding machine.

In regards to the sixth characteristic of the carding machine for the bundled fibers in the present invention, the width of the flow path for the bundled fibers in the multistage carding unit becomes more orderly, stepwise or continuously, from upstream to downstream, and carding of the bundled fibers is progressed to adjust for this widening, as the bundled fibers

move from upstream to downstream, to pass the carding unit in each stage, smoothly yielding a carded sheet.

In regards to the seventh characteristic of the carding machine for the bundled fibers in the present invention, the feed roll is placed vertically to the shaft and the supply position of the bundled fibers to the guide roll at the entrance of the carding action section sways little when compared to the conventional machine, which has the shaft of the feed roll horizontally. Furthermore, the degree of swaying of the bundled fibers is absorbed along the circumference of the guide roll so that the feed roll is not required to traverse the shaft direction, and the structure of the supporting action section can be simplified and the required space for the installation of the feed roll can be reduced.

As it relates to the structure of eighth characteristic of the carding machine for the bundled fibers in the present invention, more than one of the said feed rolls is installed, more than one set of bundled fibers are fed from each feed roll to be carded at the carding unit to yield a wide carded sheet. Furthermore, as each shaft of multiple feed rolls is positioned vertically, more than one feed roll can be placed close to each other to achieve a multiple spindle carding machine, which was difficult to obtain previously.

In regards to the setup of the ninth characteristic of the carding machine for the bundled fibers in the present

invention, more than one carding unit is aligned in parallel but orthogonal to the moving direction of the bundled fibers, and more than one set of bundled fibers from the multiple feed rolls can travel over more than one carding unit that is aligned in parallel, to simultaneously card so as to give a multiple spindle sequential carding machine that can produce a wider carded sheet, which was previously difficult to obtain.

Relating to the structure of the tenth characteristic of the carding machine for the bundled fibers in the present invention, the multistage carding unit is placed in the moving direction of the bundled fibers, and/or more than one carding unit is placed in parallel but orthogonal to the moving direction of the bundled fibers to consolidate into a sequentially integrated form, sharing at least a part of the component materials for the fluid flow path, spacer, and guiding part. Not only is a wide carded sheet smoothly obtained, but also the number of component parts is reduced to save on material costs when compared to the alignment of more than one carding unit in series or in parallel in multistage. Furthermore, the length and/or width in the sequentially integrated carding unit can be reduced to achieve miniaturization, weight reduction and cost saving of the carding machine.

According to the eleventh characteristic of the carding machine for the bundled fibers in the present invention, a sizing agent sticking to the bundled fibers is heated to melt

in the carding unit that is heated by a fluid to weaken the bonding force between the reinforced fibers forming the bundled fibers, improving the carding efficiency of the bundled fibers.

In regards to the twelfth characteristic of the carding machine for the bundled fibers in the present invention, the bundled fibers are heated by heating the guiding and/or supportive parts in the carding unit, and the sizing agent sticking to the bundled fibers is heated to melt and weaken the bonding force between the reinforced fibers forming the bundled fibers to improve the carding efficiency of the bundled fibers.

Relating to the thirteenth characteristic of the carding machine for the bundled fibers in the present invention, the bundled fibers are heated by the guiding parts and/or supportive parts with a built-in heater, and the sizing agent sticking to the bundled fibers is heated to melt and weaken the bonding force between the reinforced fibers forming the bundled fibers, improving the carding efficiency of the bundled fibers.

In relation to the fourteenth characteristic of the carding machine for the bundled fibers in the present invention, the bundled fibers are heated by the guiding and/or supportive parts which in turn has been heated by a heated fluid, and the sizing agent sticking to the reinforced fibers forming the bundled fibers is heated, melting and weakening the bonding force to improve the carding efficiency of the bundled fibers.

In regards to the fifteenth characteristic of the carding

machine for the bundled fibers in this invention, the bundled fibers are heated by the heated fluid ejected from the slits of the pipe shaped guiding parts and/or supportive parts, and the sizing agent sticking to the bundled fibers is heated, melting and weakening the bonding force between the reinforced fibers forming the bundled fibers, and drastically improve the carding efficiency of the bundled fibers via the carding action of the heated fluid.

Brief description of drawings

Figure 1 is a front view of the airflow carding machine for a single spindle bundled fiber according to the first embodiment in the present invention.

Figure 2 is a schematic planar view of the supply unit for the bundled fibers according to the machine in Figure 1.

Figure 3 is an enlarged planar view of the multistage airflow carding unit according to the machine in Figure 1.

Figure 4 (A) is a front sectional view of the first stage airflow carding unit according to the multistage airflow carding unit in Figure 3.

Figure 4 (B) is a side view of the first stage airflow carding unit according to the multistage airflow carding unit in Figure 3.

Figure 4 (C) is a side view of the second stage airflow carding unit according to the multistage airflow carding unit

in Figure 3.

Figure 4 (D) is a side view of the third stage airflow carding unit according to the multistage airflow carding unit in Figure 3.

Figure 5 (A) is a schematic planar view of the components in the airflow carding machine for multiple spindle bundled fibers according to the second embodiment in the present invention.

Figure 5 (B) is a schematic frontal view of the components for the machine in Figure 5 (A).

Figure 6 (A) is a partly enlarged planar view of the sequentially integrated airflow carding unit in the airflow carding machine for the multiple spindle bundled fibers in Figure 5.

Figure 6 (B) is an enlarged frontal view of the sequentially integrated airflow carding unit in Figure 6 (A).

Figure 6 (C) is an enlarged frontal view of the key components in Figure 6 (B).

Figure 7 is a schematic frontal view of the multistage airflow carding machine for the double decked form of the multiple spindle bundled fibers in the third embodiment of the present invention.

Figure 8 is a front sectional view of the airflow carding unit according to the fourth embodiment of the present invention.

Figure 9 is a schematic frontal view of the airflow carding machine according to the fifth embodiment of the present invention, wherein the airflow carding unit in Figure 8 is used.

Figure 10 is a schematic frontal view of the front feeder in the airflow carding machine in Figure 9.

Figure 11 is a schematic enlarged frontal view of the fiber height detection unit in the airflow carding machine in Figure 9.

Figure 12 (A) is a schematic planar view of the carding machine for the multiple spindle bundled fibers according to the sixth embodiment of the present invention.

Figure 12 (B) is a schematic frontal view of the carding machine for the multiple spindle bundled fibers in Figure 12 (A).

Figure 13 (A) is an enlarged side view of an upstream feed roll in a stationary state of the bundled fibers in the airflow carding machine for the multiple spindle bundled fibers in Figure 12.

Figure 13 (B) is an enlarged frontal view of the feed roll in Figure 13 (A).

Figure 13 (C) is an enlarged frontal view of the feed roll in the fed state in Figure 13 (A).

Figure 14 is a schematic frontal view of the carding machine for the double decked form of the multistage multiple spindle bundled fibers according to the seventh embodiment of

the present invention.

Figure 15 (A) is an exploded perspective view of the key parts, showing the support structure of the supportive part in a different embodiment in the carding machine for the multiple spindle bundled fibers in the present invention.

Figure 15 (B) is a vertical sectional view of the support structure of the supportive parts in the carding machine for the multiple spindle bundled fibers in Figure 15 (A).

Figure 16 (A) is a schematic sectional view in the embodiment of the airflow carding unit comprised of heated gas.

Figure 16 (B) is an enlarged sectional view of the embodiment of the pipe shaped guiding and/or supportive parts equipped with a built-in heater.

Figure 16 (C) is an enlarged sectional view of the embodiment, wherein the guiding and/or supportive parts are pipe-shaped and circulated with heated fluid through the inside of hollow pipe.

Figure 16 (D) is an enlarged sectional view illustrating wherein the guiding and/or supportive parts have the pipe shape and slits that cross the carded sheet and heated gas is circulated inside the hollow pipe.

Figure 17 is a schematic frontal view in a conventional airflow carding machine for the bundled fibers.

Figure 18 is a schematic frontal view of a conventional airflow carding machine for the multistage bundled fibers.

Figure 19 (A) is a schematic frontal view of the feed unit of the bundled fibers that illustrates one of problems in the conventional machine in Figure 18.

Figure 19 (B) is a schematic planar view of the feed unit of the bundled fibers in Figure 19 (A).

Best mode for carrying out the invention

Various embodiments according to the present invention are described below with reference to the accompanying drawings.

(First embodiment)

Figure 1 shows a frontal view of the airflow carding machine for a single spindled bundled fiber according to the first embodiment in the present invention. In Figure 1, a unit 10 is the bundled fiber feeding unit (filament feeding unit). As shown in the planar view of the key parts in Figure 2, a feed roll 13, around which bundled fibers 12 composed of a large number of reinforced filaments, such as carbon fibers, bonded by a sizing agent are wound, is supported on a table 11 positioning its shaft in the vertical direction and freely revolving around it. Part 14 is a guide roll, which changes the moving direction of the bundled fibers 12 that are fed from the feed roll 13, by approximately 90 degrees in a planar view, and its shaft is fixed vertically or freely revolving around the shaft. Part 15 is a guide roll which sends the bundled

fibers 12, that are sent from a guide roll 14, to an airflow carding action unit 20 at a certain height and is fixed or freely revolving, as later described.

Said feed roll 13 is equipped with an adjustable tension applying means 16, which applies tension to the bundled fibers 12, optimizing the tension applied to the bundled fibers 12 according to the properties and size of the reinforced filaments to form the bundled fibers 12 and the kind of the sizing agents used.

Unit 20 is an airflow carding action unit, which is composed of more than one guide roll, 21 and 22, a multistage airflow carding unit 25 that has more than one airflow carding unit (in the example drawing, three units of airflow carding units 25a, 25b, and 25c) aligned in series in the moving direction of the bundled fibers 12, and a rewind roll unit 28 to rewind the carded sheet 12a. It is then carded in the multistage airflow carding unit 25.

As shown in Figure 3 and Figures 4 (A) to 4 (D), the multistage carding action unit 25 is composed of a multistage alignment of three airflow carding units 25a, 25b, and 25c, in series, from upstream to downstream. As shown in Figure 3 and Figures 4 (A) to 4 (D), width of moving path w1, w2, and w3, for the bundled fibers 12 in each airflow carding unit 25a, 25b, and 25c becomes broader as it moves downstream in the moving direction of the bundled fibers ($w1 < w2 < w3$). Except for the

width, as will be described later, each airflow carding unit 25a, 25b, and 25c has a very similar structure.

Therefore, the airflow carding unit 25a will be used to illustrate our example. Airflow carding unit 25a has an airflow wind tunnel, such as a hollow rectangular wind tunnel 250 that forms a suction wind tunnel sucked from the lower side. It is also equipped with large diameter guiding parts 252 and 253, which extend to sideboards 251 on both ends and are placed before and after the moving direction of the bundled fibers 12. They are orthogonal to the moving direction of the bundled fibers 12 and horizontal. The unit is also equipped with more than one small diameter supportive part 254 placed at a certain interval between the guiding parts 252 and 253, in the same plane and horizontally.

Guiding parts 252 and 253 and/or supportive part 254 can be fixed on sideboards 251 and 251 of the wind tunnel 250, or can be free to revolve around its shaft. If the guiding parts 252 and 253 and /or supportive part 254 are fixed to sideboards 251 and 251, the support structure is simplified, cutting production cost. If the guiding parts 252 and 253 and/or supportive part 254 are free to revolve, as is sometimes desirable, depending on the property and size of the reinforced filament forming bundled fibers 12 and the kind of sizing agent, the moving and carding of bundled fibers 12 become smoother, reducing wear by friction with the bundled fibers 12 and

preventing uneven wearing by constantly changing the friction location to circumference direction.

Inside of each of sideboards 251 and 251, the guiding parts 256 and 256 regulates the crosswise movement of the bundled fibers 12 and are placed by flexible spacer parts 255a, 255b, and 255c that are slightly higher than the guiding parts 252 and 253 to control the vertical positioning of the bundled fibers 12. Increasing the height of the said guiding parts 256 and 256 makes the airflow in the airflow carding unit a stable laminar flow and stabilizes the carding action of the bundled fibers 12. However, increasing beyond a certain level does not give higher stabilization of the carding action by the stabilization of airflow. Rather it gives rise to a larger size and higher cost of the machine. Therefore, height of the guiding parts 256 and 256 is to be properly determined according to the properties and size of the reinforced filament in the bundled fibers 12 and the kind of the sizing agent used.

Sideboards 251 and 251 that are on both sides, spacer parts 255a, 255b, and 255c, and guiding parts 256 and 256 in the aforementioned airflow carding units 25a, 25b, and 25c are tied together with bolts 257 and 257 while being able to be dissembled. Screw hole 258 to fix the guiding parts is drilled into sideboards 251 and 251 in each airflow carding units 25a, 25b, and 25c, such as to match the end of the moving direction of the bundled fibers.

Thickness t1, t2, and t3 of each spacer 255a, 255b, and 255c in airflow carding units 25a, 25b, and 25c, are placed along the moving direction of the bundled fibers 12 in descending order t1 > t2 > t3. Namely, the thickness decreases in moving downstream such as where the width of moving path, w1, w2, and w3 for bundled fibers 12 formed between the guiding parts 256 and 256 are in the order of w1 < w2 < w3, where the width increases as it moves downstream. This configuration makes the width of the carded sheet 12a adjustable with the progress of carding of bundled fibers 12. Spacers 255a, 255b, and 255c and guiding parts 256 and 256 are consolidated by bolts 257 and 257 for sideboards 251 and 251 in order to allow for the sharing of components except for the spacers in the airflow carding units 25a, 25b, and 25c, giving added flexibility in the assembly and disassembly of the parts by exchanging the spacers 255a, 255b, and 255c with different thicknesses, t1, t2, and t3.

The carding action in the aforementioned airflow carding machine for the single spindled bundled fibers is described next. The bundled fibers 12 are drawn out from the feed roll 13 to change the moving direction by approximately 90 degrees within a horizontal plane by a guide roll 14 and is kept at a certain height by a guide roll 15 to draw out to the airflow carding action unit 20.

The bundled fibers 12 traveling through the guide rolls 21 and 22 that have a tape shaped or elliptical cross-section

are drawn out in the moving direction to be carded at the airflow carding unit 25, forming the carded sheet 12a. This sheet is composed of crosswise lining of each reinforced filaments, which are then rewound around a rewinding roll unit 28.

As bundled fibers 12 are drawn out from the feed roll 13, which is stacked in a vertical direction, the drawn out height of bundled fibers 12 can be moved up and down. However, the bundled fibers 12 that are drawn out change its direction by approximately 90 degrees in planar view by a guide roll 14 that is stacked vertically and are pressed from above and below by a guide roll 15 that is placed horizontally. Therefore, the bundled fibers 12 only pitch slightly at the entrance of guide roll 15. Furthermore, since the shaft of guide roll 15 is placed horizontally, the bundled fibers 12 are guided along the circumference of guide roll 15. When compared to the conventional machine, in which the shaft of both feed roll A and guide roll 2 is placed horizontally as shown in Figures 19 (A) and 19 (B), swaying of the feed position for the bundled fibers 12 that are fed through guide roll 15 is extremely low. This leads to stabilization of the supply position in the bundled fibers 12 towards the airflow carding action unit 20. As in the conventional machine, the feed roll is not required to traverse towards the shaft direction and the required space for the installation of feed roll 13 can be reduced.

Since a proper level of load is applied to the feed roll

13 by the tension applying means 16, a proper level of tension is applied to the bundled fibers 12 drawn out from the feed roll 13. Both the tension by the tension applying means 16 at the feed roll 13 and the rewinding tension by the rewind roll unit 28 constantly apply proper tension to both bundled fibers 12 and carded sheet 12a.

Since each airflow carding units 25a, 25b, and 25c in the multistage airflow carding unit 25 are equipped with guiding parts 252 and 253 and more than one supportive part 254 that are placed in a plane and horizontally, a downward airflow in the suction wind tunnel keeps the bundled fibers 12 in contact with the planar and horizontal supporting part 254 so as to constantly maintain them in a plane and horizontally. Therefore, as shown in Figure 17, the fiber height detection units 5_1, 5_2, and 5_3 are not required to install in each of the airflow carding units 25a, 25b, and 25c. Therefore, as in the conventional case, its detection signal is not required to feedback to the driver motor of the drive roll for front feeders 2_1, 2_2, and 2_3. The upstream front feeder and driver motor in each airflow carding unit 25a, 25b, and 25c can be omitted to drastically reduce the number of machine parts, shortening the total length of airflow carding action unit 20, and possibly achieving miniaturization, weight reduction, and lowering the cost of the whole airflow carding machine.

As described above, the fiber height of the bundled fibers

12 and carded sheet 12a are kept in a plane and horizontally by guide parts 252 and 253 and more than one supporting parts 254 in each airflow carding unit 25a, 25b, and 25c. Further, they are smoothly carded in airflow carding units 25a, 25b, and 25c by adjusting the tension applying means 16 of feed roll 13 and the number of revolutions of the driver motor for the rewind roll unit 28. Adjusting the tension to a constant level in rewinding carded sheet 12a to the rewind roll unit 28 eliminates pitching of the rewound carded sheet 12a to yield a roll of high quality carded sheet 12a.

According to the carding machine for the single spindle multistage bundled fibers described above, the carding action, in which the bundled fibers 12 or carded sheet 12a travels over each airflow carding unit 25a, 25b, and 25c and passes over more than one supportive parts 254, is performed at small intervals, stepwise, and continuously when compared to the carding action by a conventional wind tunnel, leading to more reliable carding and an improvement in the quality of the carded product.

Since the bundled fibers 12 or carded sheet 12a travels over each airflow carding unit 25a, 25b, and 25c and is kept horizontal by more than one supportive part 254, it is not required to install a fiber height detection unit, in which a front feeder is installed upstream of each airflow carding unit, 25a, 25b, and 25c to detect the fiber height of the bundled fibers 12 or carded sheet 12a that travels over each airflow carding

unit, 25a, 25b, and 25c and feedbacks the detected signal to a driver motor of the upstream front feeder. Along with the elimination in the need of the front feeder and its driver unit, it is also not necessary to have a processing and controlling unit for the detected signal. This not only simplifies its structure and reduces cost, but also eliminates the required space for installation, reducing its size, weight, and cost of the whole airflow carding machine for the bundled fibers. These effects become more obvious as the number of stage installed of the airflow carding units 25a, 25b, 25c, etc., for the multistage airflow carding unit 25 is increased.

As wider carded sheet 12a is required, a large number of feed roll 13 placed in parallel may be used for the sheet. However, in the case where a shaft of the feed roll A is placed horizontally in the conventional airflow carding machine as shown in Figure 17 or Figure 19, it is necessary to traverse the feed roll in the shaft direction orthogonal to its drawn out direction along with drawing out bundled fibers 12, resulting in a larger installation space per unit of feed roll required. As mentioned previously, it is practically difficult to obtain the airflow carding machine with many feed rolls in parallel for the multiple spindle bundled fibers.

(Second embodiment)

Figures 5 (A) and 5 (B) are a schematic planar view and

schematic frontal view of the airflow carding machine for the multiple spindle bundled fibers, wherein use of many feed rolls makes production of a wider carded sheet possible. In Figures 5 (A) and 5 (B), unit 10′ is the supply unit of the bundled fibers (filament supply unit), wherein many feed rolls 13 and so on are placed in the form of a matrix with each shaft being vertical. As a guide roll 14′, two guide rolls 14a at the first stage and 14b at the second stage are installed according to the position of each feed roll 13 and so on as to vary the angle of directional change differentially by guide rolls 14a and 14b such as to respond to the position of the feed roll 13 and so on, adjusting each bundled fibers 12 that are drawn out from second stage guide roll 14b to move in parallel and horizontally. Guide roll 15′ is made long in order to guide many bundled fibers 12.

As shown in Figures 6 (A) and 6 (B), the multistage carding unit is composed of multiple placements of three stage carding units 25a′, 25b′, and 25c′ in series, along the moving direction of the bundled fibers 12, as well as in parallel in a form of many units, orthogonal to the moving direction of bundled fibers 12 to form a sequentially integrated airflow carding machine 25′. This sequentially integrated airflow carding machine 25′ is equipped with long common guiding parts 252′ and 253′; two common space filling guiding parts 259a and 259b placed at a certain interval between common guiding parts 252′ and 253′; multiple long supporting parts 254a, 254′, and 254′ that are

horizontally placed at certain intervals, respectively between common guiding parts 252′ in the aforementioned front end and space filling guiding part 259a, between common space filling guiding parts 259a and 259b, and between common space filling guiding part 259b and common guiding part 253′ in the back end ; more than one long common guiding part 256a across three stage airflow carding units 25a′, 25b′, and 25c′; and dividing board 260 that separates the suction wind tunnel for airflow carding units 25a′, 25b′, and 25c′, at each stage. Common guiding parts 252′ and 253′, space filling common guiding parts 259a and 259b, and supportive parts 254a, 254′, and 254′ can be fixed to sideboards 251 and 251′, or allowed to freely revolve, for the same reason described previously.

Supportive parts 254′ and 254′ that are placed between the space filling common guiding parts 259a and 259b and between the space filling common guiding part 259b and the common guiding part 253′ are small in diameter as depicted in Figure 3 and Figure 4. However, the supporting part 254a that is placed between the common guiding part 252′ and the space filling common guiding part 259a is larger in diameter than the supporting part 254′. This configuration emphasizes an increase in carding efficiency by using smaller diameter supportive part 254′ in the first stage airflow carding unit 25a′ and the second stage airflow carding unit 25b, which increases the airflow area in the wind tunnel and easing the

suction airflow through the bundled fibers 12, as well as between each reinforced filament of the carded sheet 12a that travels through the suction wind tunnel. In addition, because carding in the third stage airflow carding unit 25c′ is fairly progressed, it mainly retains the carded sheet 12a in a horizontal position rather than increasing the carding effect.

As shown in Figure 6 (C) in an enlarged view, supportive part 254a in the third stage airflow carding unit 25c′ is dropped into semicircular grooves 251a and 251a at the upper ends of sideboards 251′ and 251′. Since supportive part 254a protrudes above the tops of the sideboards 251′ and 251′, the carded sheet 12a that travels over it, receives the carding action over the continuous wind tunnel tube without the dividing board, making the adjacent carded sheets align tightly, without a void between them, yielding a continuously aligned carded sheet.

Each common guiding part, 256a along the moving direction of the bundled fibers 12 is set up with thickness t1, t2, and t3 for the first stage airflow carding unit 25a′, the second stage carding airflow unit 25b′ and the third stage airflow carding unit 25c′, respectively, such as $t1 > t2 = t3$. Therefore, width w1, w2, and w3 between each common guiding part 256a and 256a of the moving path of the bundled fibers 12 and carded sheet 12a has a setup of $w1 < w2 = w3$.

In the above said carding machine for the multiple spindle bundled fibers, bundled fibers 12 are drawn out from many feed

rolls 13 and so on, changing its direction by each guide roll 14′ (14a and 14b), passing through guide roll 15′ to be continuously carded at the first, second, and third airflow carding units 25a′, 25b′, and 25c′ in the sequentially integrated airflow carding unit 25′ and rewound around rewind roll unit 281′ of the rewind roll unit 28′.

Therefore, the airflow carding machine for the multiple spindle bundled fibers which was previously difficult to obtain, can now be accomplished. More specifically, the sequentially integrated airflow carding unit 25′ has neither multistage alignment of the first stage, second stage, and third stage airflow carding units 25a′, 25b′, and 25c′ in series as depicted in Figure 3, nor is the alignment of each airflow carding unit in parallel in the widthwise direction. Rather, it commonly shares the space filling common guiding parts 259a and 259b and the common guiding part 256a to construct the sequentially integrated structure, resulting in the simplification of the composition, miniaturization, weight reduction, and control of cost increases, in comparison to one with a comparable number of the sequential units in series or in parallel.

Even when the supportive parts 254′ and 254a are placed horizontally, the bundled fibers 12 travel over more than one supporting part 254′ and 254a placed in a small interval, applying the carding action in the conventional wind tunnel pipe stepwise at short intervals and continuously, to make carding

reliable and improve the carding quality. In comparison to the case where the airflow direction is using a crescent alignment, the height of the single sequential airflow carding unit 25′ can be reduced.

(Third Embodiment)

Figure 7 shows a schematic composition of the airflow carding machine for the multiple spindle bundled fibers, wherein the multiple airflow carding machines for the multiple bundled fibers are placed in double decked alignment at certain intervals to eliminate operational shutdown during the exchange of feed rolls 13a, 13b, etc.

Namely, as the bundled fibers 12 on feed roll 13a runs out, the empty feed roll 13a is detached and a new feed roll 13a has to be put in its place, but the carding machine has to be stopped during this exchange of feed roll 13a. Since the airflow carding machine for the multiple spindle bundled fibers is equipped with many feed rolls 13a, the time required for the exchange of feed roll 13a becomes longer and the duration of machine stoppage also becomes longer. Then, in the airflow carding machine for the multiple spindle bundled fibers in Figure 7, more than one feed unit for the bundled fibers, 10′a, …, 10′n, and more than one airflow carding action unit, 20a′, …, 20′n, and more than one rewind roll unit, 28′a, …, 28′n are placed in multistage in double decked form at certain intervals.

Therefore, while bundled fibers 12 are carded by feeding the upper feed unit of the bundled fibers (filament feed unit) 10'a and in the upper airflow carding action unit 20'a, the bundled fibers 12 are also put on the lower feed unit of the bundled fibers (filament feed unit), 10'b, …, 10'n and in the airflow carding action unit, 20'b, …, 20'n. Immediately after the carding process by the upper feed unit of the bundled fibers 10'a and the upper airflow carding action unit 20'a is completed, carding of the bundled fibers 12 is initiated in the lower feed unit of the bundled fibers (filament feed section) 10'b and the lower airflow carding action unit 20'b. When the bundled fibers 12 are carded in the lower feed unit of the bundled fibers (filament feed unit) 10'b, and the lower airflow carding action unit 20'b, the bundled fibers 12 are put on the upper feed unit of the bundled fibers (filament supply unit) 10'a and the airflow carding action unit 20'a. Hence, the bundled fibers 12 can be continuously carded.

As the number of upper and lower stages has more surplus, the bundled fibers 12 can be carded simultaneously on more than one feed unit of the bundled fibers (filament feed unit) 10' and the airflow carding action units 20'. It is also possible that both an upper stage and a lower stage setup are set in combination and alternately operated, to card bundled fibers in every other spindle and rewind around a rewind roll the carded reinforcing filaments that are carded in every other spindle,

without void between them, continuously producing a carded sheet.

In the embodiment of Figure 7, an example wherein the bundled fibers 12 and the carded sheet 12a travel horizontally from the left end of the figure to rewind around the rewind roll unit 28 at a right end is described. It is also possible that at least the airflow carding units 25'a and 25'b are vertically placed such that the bundled fibers 12 travel from top to bottom in one unit, then travel from bottom to top in another, changing the moving direction of the bundled sheets 12a and 12b sent from the upper and lower airflow carding units 25'a and 25'b by 90 degrees. By changing the direction of roll so that it travels horizontally, a pair of carded sheets 12a and 12b in parallel can be aligned to yield a single wide carded sheet. Alternatively, each reinforcing filament for carded sheet 12a and that of carded sheet 12b are alternately placed in the odd and even number positions, respectively, to produce a wide carded sheet.

(Fourth Embodiment)

In the above embodiment, the case wherein more than one supportive part 254, 254', and 254a in the airflow carding units 25, 25a, 25b, 25c, 25'a, 25'b, and 25'c are placed in a plane and horizontally along the moving direction of the bundled fibers 12 and carded sheet 12a is described. However, as shown

in Figure 8, multiple supporting parts 254 can be placed in a convex crescent form against the airflow direction. The airflow carding unit with convex placement of this supportive unit can be a single carding machine for the bundled fibers as shown in Figure 1, a multistage airflow carding machine as shown in Figure 3, a multistage multiple sequential airflow carding machine as shown in Figure 5, or a double decked multistage carding machine for the multiple spindled bundled fibers as shown in Figure 7. In these cases, it is possible that the tension of feed roll 13 and the rewind tension can properly be adjusted by the tension applying means 16 and the rewind roll unit 28, respectively, transforming the bundled fibers 12 and carded sheet 12a into a convex crescent form along multiple supportive parts that are placed in a crescent form. As in the case where more than one supportive part is placed horizontally, the fiber height detection unit, the upstream feed roll, and the downstream feed roll can also be omitted.

(Fifth Embodiment)

As shown in Figure 8 mentioned above, it is possible to place more than one supportive part 254 in a crescent form, where if necessary, an upstream feed roll unit 23 can be placed downstream of the guide rolls 21 and 22 as shown in Figure 9. Downstream of this feed roll unit 23, namely upstream of the airflow carding unit 25, the fiber height detection unit 24 can

be placed, or downstream of the fiber carding unit 25, the downstream feed roll unit 26 and the fiber height detection unit 27 can be placed.

Since upstream feed roll unit 23 and downstream feed roll unit 27 have the same composition, the upstream feed roll unit 23 will be described as an example. As shown in Figure 10, the feed roll unit is comprised of the drive roll 231, freely revolving roll 232 and 233, guide rolls 234 and 235, retaining part 236, and air cylinder 237. The drive roll 231 is driven by a driver motor, which cooperates with the freely revolving rolls 232 and 233 to draw out the bundled fibers 12. Guide rolls 234 and 235 feed the bundled fibers 12 from a certain direction to the space between the said drive roll 231 and the freely revolving rolls 232 and 233. Retaining part 236 holds the said freely revolving rolls 232 and 233 and air cylinder 237 as an actuator to raise or lower this retaining part 236, and raising and lowering of the said holding part by piston rod 238 of the air cylinder 237 applies a required load to the freely revolving rolls 232 and 233 against the drive roll 231 to send the bundled fibers 12.

Fiber height detection units 24 and 27 have the same composition and the fiber height detection unit 24 will be described as a representation. As shown in Figure 11, the detection unit is equipped with a pair of fixed or freely revolving guide rolls 241 and 242 that are placed before and

after the moving direction of the bundled fibers 12 at a certain interval to move the bundled fibers 12 over these guide rolls 241 and 242. Then, the bundled fibers 12 that have been sent by feed roll unit 23 under an overfed condition, is bent into a crescent form by airflow between guide rolls 241 and 242, where the level of the bending of the bundled fibers is detected by a photoelectric or displacement sensor 243.

While the carding machine for single bundled fibers shown in Figure 9, mentioned above, performs essentially the same carding action as the carding machine for the single bundled fibers depicted in Figure 1, functional differences in the installation of the upstream feed roll unit 23, the fiber height detection unit 24, the downstream feed roll unit 26, and the fiber height detection unit 27 will be described. The mass that is fed by the upstream feed roll unit 23 is set slightly larger than that by the downstream feed roll unit 26, leading to an overfed condition. Therefore, the bundled fibers 12 can be bent as much as the overfed mass in the fiber height detection unit 24 and the multistage carding machine unit 25. The bent condition in the fiber height detection units 24 and 27 can be stabilized by the action of the suction system or through lightweight superposition.

The fiber height detected by the fiber height detection unit 24 is sent to the drive roll 231 of the feed roll unit 23 as shown in Figure 10, whereby starting or stopping the drive

motor allows for the adjustment of the mass of the bundled fibers 12 fed, optimizing the overfed mass to a proper amount.

The fiber height of the carded sheet 12a that is detected by the fiber height detection unit 27 is sent to the driver motor of the rewind roll unit 28 to adjust the rewind tension of the carded sheet 12a by rewind roll unit 28 at a constant. This eliminates pitching of the carded sheet 12a that is rewound to yield a roll of high quality carded sheet 12a.

(Sixth Embodiment)

As shown in Figure 12, the carding machine for the multiple spindle bundled fibers can have an upstream feed roll unit 23′, a fiber height detection unit 24′ and a downstream feed roll unit 26′.

As shown in Figure 13 (A), the upstream feed roll unit 23′ is composed of a long common drive roll 231′, many separate freely revolving rolls 232 for each bundled fibers 12, and many separate air cylinders 237 separate freely revolving rolls 232. When the overfed amount of the bundled fibers 12 is large, as shown in Figures 13 (A) and 13 (B), each separate freely revolving roll 232 is raised by each separate air cylinder 237 to temporarily stop the feeding of the bundled fibers 12. As the amount of overfed mass becomes a proper value, as shown in Figure 13 (C), each separate air cylinder 237 pushes down each separate freely revolving roll 232 in cooperation with the drive

roll 231′ to independently draw out the bundled fibers 12.

(Seventh Embodiment)

As shown in Figure 14, the double decked multistage carding machine for the multiple spindle bundled fibers can be equipped with an upstream feed roll unit 23′a and the fiber height detection unit 24′a to replace the guide roll 15 or in conjunction with the guide roll 15.

Figures 15 (A) and 15 (B) show other embodiments with a structure of the supportive part in the carding machine for the multiple spindle bundled fibers in accordance with the present invention. As described in Figure 3, Figure 4, and Figure 6, a structure of more than one supportive part 254 and 254′ in the airflow carding units 25 and 25′ has a drilled hole through the sideboard 251, spacer 255, and guide part 256. Support parts 254 and 254′ are inserted into this hole. However, it is complicated to insert many small diameter supporting parts 254 and 254′ into many small diameter drilled holes.

Then, in the airflow carding unit 25″ in the embodiment shown in Figures 15 (A) and 15 (B), the top of sideboard 251 is cut to form more than one slit 251b to a certain depth and the supporting part 254 is inserted into this slit 251b. In this support structure, in which the supporting part 254 is inserted into the slit 251b, assembly of the supporting part 254 with the sideboard 251 is much easier and can be completed

within a short time of period as compared to insertion of the supportive part 254 into the drilled hole.

In the support structure where the supportive part 254 is inserted into the slit 251b, as required and shown in the figure, a female screw 251c is drilled into both tops of sideboard 251, which is covered with an approximately U-shaped cap 260 that is tightened with a screw 261. A flat plate 260a, a downward vertical plate 260b that hangs from both ends, and a drilled hole 260c are located such that they match up with the female screw 251c of the aforementioned flat plate 260a. This arrangement prevents the supportive part 254 from rising in slit 251b and dropping from slit 251b.

The embodiment of Figures 15 (A) and 15 (B) shows only the sideboard 251. However, as described previously, as spacer 255 and guiding part 256 are used together with the sideboard 251, a slit can be cut at the same pitch and depth into spacer 255 and guiding part 256 as in sideboard 251, so that the supporting part 254 can be inserted into this slit. If required, sideboard 251, spacer 255 and guiding part 256 are covered with said similar cap 260 and then tightened with the screw.

In the above embodiment, it was described that the sideboard 251 is cut to form a deep slit, 251b, and the supporting part 254 is supported at a lower position than the top of the sideboard 251. It is acceptable that sideboard 251 is cut to form a shallow slit and the upper part of the supporting part

254 is supported at the same height as the top of sideboard 251. In this case, the cap 260 can be a flat plate.

In the above embodiment, it was described that the supporting part 254 is placed in a plane and horizontally, similar to those in Figure 4 and Figure 6. However, similar to the case in Figure 8, the cut of each slit can be in a crescent form so that the supporting part 254 can be inserted in a crescent form.

In the above embodiment, temperature of air stream flowing into the airflow carding unit 25 through the wind tunnel is not specifically described. However, depending on the kind of adhesive (sizing agent) sticking to each reinforcement filament in the airflow carding machine having a single or multistage airflow carding unit as shown in Figure 16(A), a hot air suction wind tunnel can be created in the airflow carding unit where hot air 270 can weaken the adhesion force of the adhesive (sizing agent) and promote the carding action.

In the above embodiment, it has been described that the guiding part and supportive part are solid. However, as shown in Figure 16(B), the guiding parts 252 and 253 and/or the supportive part 254 can be a pipe and these pipe-shaped guiding parts 252 and 253 and/or supportive part 254 can be equipped with a built-in cartridge heater 272 in hollow pipe 271 to heat the guiding parts 252 and 253 and/or the supportive part 254. In this setup, the bundled fibers and/or carded sheet is

properly heated by the guiding parts 252 and 253 and supportive part 254 that is heated by the cartridge heater 272 to heat and soften the sizing agent in the bundled fibers, reducing the bonding force to generate a smoother carding action.

As shown in Figure 16C, the guiding parts 252 and 253 and/or the supportive part 254 is pipe-shaped and its hollow inside 271 can be run with heated fluid 273, such as hot air, steam or hot water can be run. In this setup, the guiding parts 252 and 253 and/or the supportive part 254 is heated by the heated fluid 273 that flows in the pipe and properly heats the bundled fibers and/or carded sheet to heat and soften the sizing agent in the bundled fibers and weaken the bonding force to generate a smoother carding action.

In the carding machine for the multiple spindle bundled fibers as shown in Figure 16(D), the guiding parts 252 and 253 and/or supportive part 254 in the final stage of the airflow carding unit have a pipe shape and a slit 274 is cut in the part of the pipe-shaped guiding parts 252 and 253 and/or the supportive part 254 where the slit 274 crosses in the moving direction of the carded sheet. Then, the heated air 275 is run inside of the hollow pipe 271 of the guiding parts 252 and 253 and/or the supportive part 254, ejecting the hot air through slit 274 towards the carded sheet 12a. Due to a cooling sizing agent, this leads to the carding of the reinforced filament forming the carded sheet 12a in a uniform interval.

More than one of examples in the embodiment of the present invention are described above, but the present invention is not limited by these examples of the embodiment. The present invention is intended to include the embodiment comprising the description within the spirit and claim of the present invention. For example, while it is described in each embodiment that thickness, t, in spacer 255 and guiding part 256a can be varied stepwise, it can also be continuously varied along the moving direction of the bundled fibers 12 or carded sheet 12a to continuously increase the width, w, of the traveling path for the bundled fibers 12 or carded sheet 12a in a downstream direction.

Or depending on the kind of bundled fibers 12, the distance between the sideboards 251 and 251′ of the frames 250 and 250′ can continuously fan out towards the moving direction of the bundled fibers 12 or carded sheet 12a to continuously increase the width of the traveling path, w, for the bundled fibers 12 or carded sheet 12a.

Furthermore, it is described in the embodiment shown in Figure 4 that more than one supporting part 254 is placed in a plane and horizontally in each airflow carding units 25a, 25b, and 25c. It is also described in the embodiment of Figure 6 and Figure 7 that more than one supportive part 254a and 254′ is placed in a plane and horizontally in the multistage sequential airflow carding units 25′ and 25′a. However, those

supporting parts can be placed in a plane and either tilted upwards or downwards along the moving direction of the bundled fibers 12 in a single or multistage airflow carding unit.

In the above embodiment, an airflow wind tunnel using suction airflow was described, but airflow that is blown can also be used.

Furthermore, in the above embodiment it is described that the guiding parts 252, 253, 252′, and 253′, the space filling common guiding parts 259a and 259b, and the supporting parts 254, 254a, and 254′ are all cylindrical, namely having a constant diameter regardless of the length of the direction. However, these parts can have a large diameter at both ends in the length direction and a smaller diameter that gradually decreases towards the middle, creating a hand drum shape of the guiding parts and supporting parts. Use of these guiding parts and supportive parts can reduce the difference in the distance between the center axis line of the single fiber of the bundled fibers 12 and the reinforced filament at both ends of the carded sheet 12a to apply large tension force to the reinforced filament at both ends in the carded sheet 12a, as compared to using the cylindrical guiding parts and supportive parts.

In the above embodiment, it was described that multiple supportive parts are used in all cases. However, at least one or more supportive parts are acceptable and a single supportive part can be used. In this case, the carding effect in the

bundled fibers 12 and carded sheet 12a is lowered and stabilization of its configuration tends to be more difficult, as compared to the case when more than one supporting part is used. However, as compared to the case in the airflow carding unit without a single supportive part, the carding action occurs before and after the supporting part to lead not only to substantially smoother carding action, but also stabilize the configuration of the bundled fibers and/or carded sheet because the bundled fibers and/or carded sheet is supported by the supporting part. Both the tension applying means and the tension applied by the rewind roll to bundled fibers 12 and carded sheet 12a can further stabilize bundled fibers 12 and carded sheet 12a even if the support is performed by a single supporting part.

Furthermore, it was described in the above embodiment that the tension applying means 16 is placed on each feed roll 13. However, each feed roll 13 can revolve in reverse and instantly apply tension to the bundled fibers 12. For example, it is possible that a pulley be installed on the shaft of each feed roll 13 and placed with a belt working as a driving force that delivers means for a single driver motor to revolve the roll under low tension in the opposite direction of the bundled fibers 12, resulting in the application of an overall constant desired tension to multiple bundled fibers 12. A fact that tension is always applied to the bundled fibers 12 prevents the

bundled fibers 12 from loosening and keeps them stretched, when the carding process is temporarily stopped. When the carding process is restarted, the initial setup for the bundled fibers can almost be omitted. Application of a required tension to many bundled fibers 12, on the whole, can possibly keep costs down.

The airflow carding machine for the bundled fibers in the present invention is comprised of a feed roll wound with the bundled fibers; the airflow carding unit to card the bundled fibers drawn out from this feed roll with the airflow orthogonal in the moving direction of the bundled fibers; and the rewind roll to rewind the carded sheet that is carded in the airflow carding unit. Since the said airflow carding unit is characterized by having more than one supportive part that is placed at a certain interval along the moving direction of a single or multiple bundled fibers, the carding action of the bundled fibers and carded sheet that travels over a single supportive part or multiple supportive parts in a short distance is applied. This is either applied, at a minimum, twice before and after the supporting part as the carding action of the conventional wind tunnel tube, or stepwise and continuously to make the carding reliable and of better quality.

Furthermore, since the configuration of the bundled fibers or carded sheet is always kept constant along the supporting part of the airflow carding unit, it becomes

unnecessary to have a front feeder upstream of the airflow carding unit, or a fiber height detection unit in the airflow carding unit to feedback the fiber height detected to the driver motor for the drive roll of the front feeder to adjust for the overfed condition. Therefore, not only are the number of various component parts, such as the fiber height detection unit, the front feeder, and its driver motor reduced to save parts cost, but also the installation space for these components becomes unnecessary, simplifying the composition to achieve miniaturization, weight reduction and lower cost.

The above effect becomes more pronounced with the increase in the number of stages, as multiple airflow carding units are placed in multistage along the moving direction of the bundled fibers. Furthermore, when the width of the traveling path of the carded sheet in more than one airflow carding unit is increased stepwise or continuously downstream in the moving direction of the carded sheet, an orderly response to the increase in width of the bundled fibers and carded sheet, along with carding of the bundled fibers and carded sheet in the airflow carding unit, achieves smooth continuous carding.

In the present invention, as the shaft of the feed roll of the bundled fibers is placed in the vertical direction, even if the feeding position of the bundled fibers that are drawn out from the feed roll is altered vertically, there is little variation in the supply position in relation to the airflow

carding action unit so that the feed roll is not required to traverse towards its shaft direction as in a conventional airflow carding machine where the shaft of the feed roll is placed in a horizontal direction. This can reduce the required installation space for the feed roll and achieve feeding of more than one bundled fibers in the airflow carding machine for the multiple bundled fibers, which was previously difficult to achieve.

In the above embodiment, a simple airflow carding machine was described in all cases. However, the carding machine in the present invention can be used when the carding machine is based on fluids, such as water or oil.

Industrial Applicability

The carding machine for the bundled fibers in the present invention can easily and reliably card the bundled fibers collected from many reinforcing filaments to manufacture a carded sheet. The carded sheet that is manufactured accordingly can be used as the fiber reinforced composite material impregnated into a matrix; it has broad application in aerospace, land transportation, shipping, building, construction, industrial parts, and sporting goods.